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Look Out EPROMs, Here Comes Flash

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LOOK OUT EPROMs, HERE COMES FLASH

AS THE LAPTOP BOOM SPARKS MEGAGROWTH IN NONVOLATILE MEMORY, THE PLAYERS ARE LINING UP AT BAT

BY SAMUEL WEBER

MEMORIES

IN THE WORLD OF NONVOLatile memory, flash is where the action is. As technology advances and push densities higher and costs lower, memory vendors are anticipating an explosion of applications for this versatile device. They are casting covetous eyes at the current $3 billion market for the venerable ultraviolet-erasable EPROM and the high-density segments of the more sophisticated full-featured electrically erasable PROM (EEPROM). Some even speculate that as speeds get better than 100 ns, some RAM applications may fall to flash as well.

The potential market size and growth rate are so attractive that old-line semiconductor vendors like Advanced Micro Devices, Hitachi, Mitsubishi, Signetics, and Texas Instruments are mounting big efforts with first-time flash products to join battle with companies already in the market. These include market leader Intel Corp., along with smaller but experienced flash suppliers like Atmel, Catalyst, and Seeq. Exel, NEC, and Waferscale are also expected to launch products soon.

One factor driving the growth of flash is the boom in portable, laptop, and palm-size computers, expected to grow fivefold to 11 million units by 1994. They offer a big opportunity to suppliers of an all-solid-state substitute for floppy and hard disks (see p. 52). In this market, flash offers distinct gains in size, power dissipation, reliability, and speed.

"At the 4-meg level," says Robert Tabone, Hitachi Ltd.'s product marketing manager for static RAMs in Brisbane, Calif., "suddenly we will have memory cards with the density to rival a hard disk. While the cost won't be at parity then, by 1994 we expect that to occur. With the explosion of laptop and notebook computers and many applications requiring high density, this technology is absolutely going through the roof."

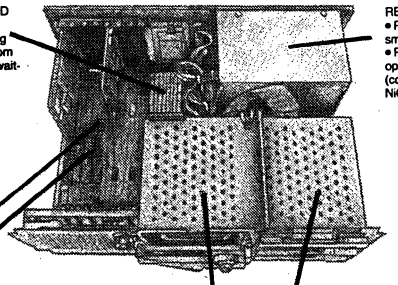
There are literally thousands of applications for low-cost, high-density electrically reprogrammable memory in automotive, telecom, point of sale, computer peripheral, industrial control, instrumentation, military, medical, and many other areas where large numbers of sockets await. All this means that flash sales will swell from a small base of $37 million this year to $134 million in 1991 and $1 billion by 1994, says Mary Olsson, industry analyst for Dataquest Inc., the San Jose, Calif., market research firm.

This growth largely stems from the industry's need for an in-system programming solution, says Krish Panu, vice president of marketing and sales for Catalyst Semiconductor Inc. of Santa Clara, Calif. "Time to market is getting critical and system life cycles are getting shorter. Having in-system reprogrammability makes it easy to upgrade and modify products quickly and reliably," he says.

And flash is quick: a device can be erased and reprogrammed in less than 5 s, about half the time it takes for a full-featured EEPROM. And erasure can be done without removing the device from its socket, unlike EPROMs, which erase in about 20 min. Thus, code changes in prototypes can be made in seconds, and board updates can be done without disassembly. These are just two simple examples of the possibilities flash offers to system designers.

At this incipient stage, there are several

How Flash Enhances Systems



RESIDENT OPERATING SYSTEMS AND APPLICATIONS SOFTWARE
- With primary applications and operating systems stored and directly executed from flash, you get "instant on"—there's no waiting to load or boot.

REQUIRES LESS POWER
- PCs designed with flash memory can use smaller power supplies.
- Portables and laptops are lighter and can operate for over 60 hours on 8AA batteries (compared with today's 3 hours using heavy NiCd batteries).

UPDATABLE BIOS
- Allows instant, hands-off, even remote update of BIOS code. This results in faster time to market for OEMs, easy upgrades for end users.
- Add, modify, or optimize drivers for new hardware, memory expansion, communications, printers, advanced monitors, and new mass-storage systems.

SOLID-STATE DISK
- Gives true nonvolatility, no head crashes, no seek time, and the reliability that comes with a lack of moving parts. Extremely useful in harsh and rugged conditions.
- Unlike other solid-state disk technologies, flash does not require batteries to retain data, thereby eliminating the accidental loss of data due to battery failure.

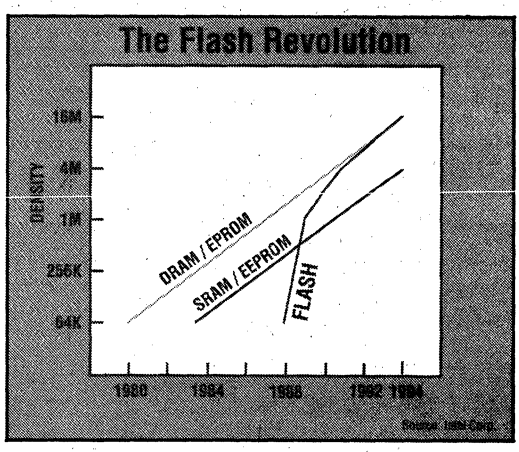
approaches to flash technology and a lack of standards, although one may be emerging in at least de facto form. Right now, chip makers follow different roads in cell size and design, method of writing and erasing, power-supply requirements, and endurance (the number of write/erase cycles that can be performed before deterioration of the gate oxide).

Each variation has advantages and disadvantages, a situation that can be confusing to potential users. Also confusing is just where flash fits in the hierarchy of nonvolatile memory options available (EPROMs, full-featured EEPROMS, battery-backed RAMs, and nonvolatile RAMS of different types). Invariably, the choice boils down to cost and system requirements. The system designer must consider such questions as frequency of writing or erasing, whether byte, page, sector, or bulk alterability is required, the density needed, power-supply availability, and price.

The multifarious designs sort themselves into two basic approaches, distinguished by whether they require one or two voltage supplies. Both can trace their lineage to EPROM technology, using a floating-gate structure but with a thinner gate oxide. But they differ in their cell structure—whether they require one or several transistors per cell. In general, the one-transistor cell requires a 12-V supply for programming and a 5-V supply for read, but yields a small cell size. This results in higher density, smaller chip size, and lower cost than the 5-V-only approach.

Intel's self-aligned stacked-gate cell, based on its proprietary ETOX (EPROM tunnel-oxide) technology, is the paradigm for the one-transistor school. At midyear, the Santa Clara firm announced the highest-density flash part currently available, the 2-Mbit 28F020. The competition either has or will shortly introduce 1-Mbit parts, and most have 4-Mbit flash devices in development. These should start to appear in late 1991.

The Intel approach received validation in the September announcement by Advanced Micro Devices Inc. of a 1-Mbit flash memory compatible with Intel's 12-V memory pinout and software-programming routines. AMD is committed to "establishing a de facto standard" for flash, says Steve Grossman, director of marketing for memory products at the Sunnyvale, Calif., company. Catalyst also follows the Intel pinout and algorithm lead in its 1-Mbit, 120-ns part, the CAT28F010, now being offered as samples. Exel, Hitachi, Mitsubishi, and Toshiba also opt for Intel compatibility.



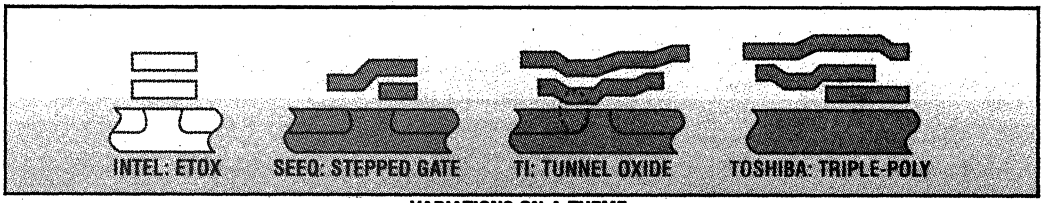
One problem with the single-transistor cell is the possibility of overerasure and consequent current leakage, resulting in false data readings. This occurs when a cell in the zero state receives an erase pulse, whereby it can be driven into the depletion mode. The column-sense amplifier can read this leakage current falsely as an erased cell. Intel and its emulators overcome this with a programming algorithm that first programs up all the cells on a chip to 1 before erasing.

Seeq Technology Inc., a major competitor of Intel's, overcomes this problem by means of a different cell structure. Its split-gate cell employs what amounts to a two-transistor architecture, but exacts only a small premium in cell area. Through a diffusion process, the split gate creates a "phantom transistor" that looks like a series transistor, says Richard Norris, marketing manager for Seeq's Memory Division in San Jose. "This allows us to isolate the cell from others in a column. The series transistor acts like a valve, and even if you overerase the cell and it gets leaky, if you don't select the transistor the leakage doesn't reach the column."

Another difference from Intel is the ability of the Seeq parts to erase a sector or small portion of the memory. With the Intel device, the entire chip must be erased before writing in new data. "We have sector-erase," says Norris. "There are 128 columns and you can erase and reprogram any one of those without altering any of the others."

Norris insists that the 15% premium on cell size and 10% on overall chip size is worth it for the advantages Seeq offers. "Furthermore, in our next-generation part, cell sizes will be within 5 mil² of [Intel's], because Intel adds a lot more external circuitry to prevent that overerase from happening." Seeq now produces two parts, the 512-Kbit 48F512 and the 1-Mbit 48F010.

The dual-power-supply requirements of most of today's flash EEPROMS add cost and space penalties for system design, and for this reason, some vendors are developing single-supply flash technology. Both Texas Instruments Inc. in Dallas and Atmel Corp. of San Jose have introduced 256-Kbit products of this



VARIATIONS ON A THEME

Chip makers are taking many routes to flash, including these, but all the designs trace their lineage to EPROM technology, using a floating-gate structure but with a thinner gate oxide.

EMBEDDED GROWTH

THE POTENTIAL POWER of embedded flash in microcontroller applications is spurring development of new devices. The embedded market could grow to $1 billion by 1992 or '93, says Bruce McCormick, vice president of marketing at Intel Corp.'s flash memory operation. A big chunk of that will be automotive, says Greg Armstrong, manager of application-specific memories at Texas Instruments Inc.'s Semiconductor Group in Dallas. Here, Armstrong says, programmable memories that now employ EPROMs for storage codes, lookup tables, and engine and transmission parameters will go flash by the end of the 1990s. This trend will be accompanied by the use of larger amounts of flash memory on automotive microcontrollers for greater system-level integration.

A case in point: at the recent Convergence Conference in Detroit, Chrysler Corp. demonstrated its Ultradrive trans-axle electronic control system. With TI flash devices and microcontrollers, it keeps the shift quality consistent throughout the life of the transmission, monitors system performance, and provides diagnostics at the assembly line and dealership.

TI is also merging its flash technology with the emerging boundary-scan JTAG (IEEE 1149.1) test standard to provide a unique device for automatically and permanently maintaining system or board history. Dubbed a testability-ported diary memory, the TMS29F816 can store diagnostic information in the on-board 5-V, 16-K flash memory.

Also recognizing the potential of this embedded market, Intel is about to introduce the 88F51FC, a CHMOS single-chip 8-bit controller with 32 Kbytes of on-chip user-programmable flash.

The Inmos Division of SGS-Thomson Microelectronics in Phoenix is taking the module approach to embedded flash by combining a 16-bit IMS T222 Transputer with 256 Kbytes of flash in a credit-card-sized module, the IMS B418 ROM TRAM. Unlike Intel's entry, the device can be block-erased in 4 Kbytes.—*S. W.*

genre, using very similar technologies. In fact, Atmel hints that the two companies are discussing mutual cooperation.

Atmel's device, which it calls a PEROM (for programmable erasable ROM) cell, uses two transistors. This eliminates the need for a high-voltage programming process because it isolates the cells being programmed from the other cells. The AT29C256 can be erased or programmed in 64- or 128-byte sectors (if desired, a bulk full-chip erase is available). The device has 160-ns read-access time and write time of 10 ms for 64 bytes (5 s full chip).

TI's TMS29F256 is based on a 1.5-transistor cell fabricated in the company's ACEE (advanced contactless EPROM) technology. For writing and erasing, it uses a tunnel diode in the channel region of the transistor cell rather than the conventional Fowler-Nordheim floating-gate structure. With access times of 170 ns, the device can be programmed 1 byte at a time or in the page mode from 2 to 64 bytes at a time. At the 256K level, TI is using a 1.5-μm ACEE process and will scale down to 1.0-μm for the 1-Mbit part. TI's 4-Mbit prototype uses 0.8-μm technology.

While flash device vendors refine device technology and tussle over the right approach, they are also taking hard aim at those beckoning sockets. Last month, Intel introduced the first flash-memory-based IC card in 1- and 4-Mbyte sizes aimed at laptop, notebook, and palm-top computers. Card densities should converge rapidly toward those of hard disks and greatly exceed those of floppy disks in the late 1990s, the company says.

The Intel cards are intended for applications in updatable application code, application-code and data-file storage, and data acquisition. They will be competing with existing memory-card technology, which includes expensive battery-backed RAM cards, unalterable ROM cards, and one-time-programmable EPROM cards. They are unsurpassed as a disk replacement in portable PCs, says Jim Weisenstein, Intel's flash-memory-card manager in Folsom, Calif. Reduced power consumption, resistance to shock, a doubling in write speed, and 3.5 times faster read time are among the benefits he cites.

Meanwhile, Microsoft Corp. of Redmond, Wash., has issued a Flash File System that runs as a software driver under MS-DOS. It effectively makes the flash-card memory behave like a disk, reacting to familiar DOS commands and storing data files sequentially.

On another front, Western Digital Corp. of Irvine, Calif., is working on a solid-state disk using flash technology with partners SunDisk Corp. of Santa Clara and AT&T Co. in Allentown, Pa. Details were scant at press time, but Ilene Graney, Western Digital's director of marketing for storage products, says the company has been involved in the project for two years. The device is not intended for general EPROM replacement but can be used for this application. It will be a 4-Mbit chip, Graney says, capable of assembly in 10-, 20-, and 40-Mbyte disk replacements potentially equivalent to a 1.6-in. disk. Access time will be under 2 ms.

Packaging is an issue in flash, and increasingly the 1-Mbit-and-higher chips are being produced in the new TSOP (thin small-outline) packages. Its small form factor of 20 by 8 by 1.2 mm makes TSOP ideal for the flash-card market as well as other embedded applications. It also is desirable for surface-mounted boards. Another possibility comes from White Technology Inc. The Phoenix company's WF1024KB-150 is an 8-Mbit flash-memory module packaged in a 34-pin, hermetically sealed metal package. It is built with eight 1-Mbit flash chips, organized as 1 Mbyte by 8, and assembled on a thick-film substrate. Each of its eight pages can be erased a page at a time. The device is guaranteed for 10,000 erase/program cycles.

Meanwhile, cell sizes for flash memories are shrinking rapidly under the assault of new approaches to cell-structure design. Intel radically trims size with a new contactless single-transistor cell. At the upcoming International Electron Devices Meeting, company researchers will describe their Flash Array Contactless EPROM (FACE) technology, which reduces the area of the ETOX cell by 55% to 8.4 μm^2. That reduction is based on 1.0-μm design rules. At 0.8-μm, the cell can be almost halved again to 2.48 μm^2.

Also at IEDM, Toshiba Corp. will show a NAND-structured memory cell of only 2.3 μm^2 (0.6-μm design rules). The cell can achieve 16-Mbit and larger flash memories, Toshiba says. Mitsubishi Corp. has achieved a single-transistor, stacked-gate cell of only 3.6 μm^2 in a 16-Mbit flash. It uses 0.6-μm design rules and achieves 5-V-only programming and erasure by a unique negative-gate-biasing erasing condition.

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LAPTOP VENDORS JOIN THE FLASH BANDWAGON

AIRIS'S VH-286 USES FLASH TO STORE BIOS, BUT THAT'S JUST THE BEGINNING OF THE APPLICATION POSSIBILITIES

BY JACK SHANDLE

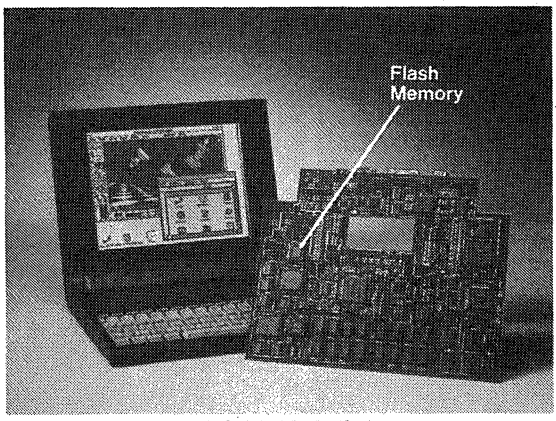
MEMORIES

WHEN THE founders of Airis Computer Corp. left Zenith Data Systems in 1988 to start a new notebook-computer firm, they knew, as all entrepreneurs must, that their product strategy had to stand out in a crowd. Flash memory technology (see p. 44) will play a major role in Airis's strategy when the first VH-286 computers start rolling off the production line this month. But Airis is unlikely to be alone for long.

Flash is versatile—it lets clever systems houses such as Airis play with innovative marketing techniques as well as advanced technology. For Chicago-based Airis, the bright idea is TeleROM, says Steve Valentor, engineering vice president. All Airis computers have built-in modems, and by combining that capability with a bank of flash memory that stores system BIOS, Airis can offer users a highly desired feature: instantly updatable BIOS. Simply by dialing into Airis's bulletin board, users will be able to update their BIOS for a nominal charge.

Software-updatable BIOS ensures compatibility with the latest features and software. There are, for example, undocumented features in IBM Corp.'s VGA graphics specification, says Valentor. As these are revealed and utilized in new applications software, Airis users will stay compatible with a phone call.

Airis dedicated 128 Kbytes of flash to BIOS updating: 32 for system BIOS, 32 for video BIOS, and 64 to a program to update the BIOS. Patents have been requested for the updating scheme. In particular, provisions must be made for the possibility that system power may be lost during the BIOS update. "You have to be sure you have enough BIOS available at all times to boot the system," Valentor says. Airis purchases its flash chips from Seeq Technology Inc., San Jose, Calif., because they offer a sector-erase feature that helps implement the fail-safe updating procedure.



INSTANT UPDATES

The BIOS in Airis's laptops is stored in a bank of flash memory. With TeleROM, BIOS can be updated by modem.

Storing BIOS is just the beginning for flash applications. John Wharton, a contributing editor to the *Microprocessor Report*, a Sebastapol, Calif.-based newsletter, says there is more to come. Conventional PC-memory systems are organized on three levels: rotating mass storage, dynamic random-access memory, and static RAM cache, he says. Each level adds expense in the form of control logic, interconnects, access time, and reliability. "If executable programs and data are all already on-line in moderately fast memory," he says, "why copy them to an intermediate DRAM first? As larger caches migrate into the central processing unit, the performance characteristics of external memory become less critical." Several companies are hard at work leveling the conventional three-tier memory architecture by means of flash-based "silicon disks."

Among them is Psion Inc. The Watertown, Conn., company employs small flash-based modules as replacements for floppy disks. And at least one company—SunDisk Corp. of Santa Clara, Calif.—is building a flash-based storage system to replace Winchester drives. Flash could even be used to store applications software, but cost and reliability in massive read/erase/write environments continue to be inhibitors to widespread acceptance.

Besides the advantages to laptop and notebook end-users, flash offers considerable advantages in manufacturing, says John Wagner, manager of Zenith Data Systems' Portable Products Development Group, Mt. Prospect, Ill. Although Zenith has not yet implemented flash, it is studying the technology closely in part because of manufacturing issues. "Producing a machine requires several stages of firmware development," he says, "and using flash memory would let us implement the latest version in the final stages of manufacturing. You can also include the latest BIOS and system configuration on a floppy."

Psion is already using flash as a floppy-drive stand-in. Its Flash Packs use 1

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